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CALCULATIONS PERTAINING TO GRADINGS AND SPECIFIC GRAVITIES

CAUTION: Prior to handling test materials, performing equipment setups, and/or conducting this method, testers are required to read **"SAFETY AND HEALTH"** in Section F of this method. It is the responsibility of whoever uses this method to consult and use departmental safety and health practices and determine the applicability of regulatory limitations before any testing is performed.

A. SCOPE

These examples illustrate: (1) acceptable methods for adjusting and/or combining gradings, and (2) methods of correcting for differences in specific gravities.

Samples, as received in the laboratory, can seldom be tested without some adjustment of gradings. These adjustments are usually necessary in order to meet specification grading requirements or to obtain a suitably graded sample for a particular test.

B. GRADING ADJUSTMENTS ON SINGLE SAMPLES

1. Single sample with oversize to be rejected. In order to compute the "as used" grading, increase to 100 % the "as received" percent passing the size on which the sample is to be scalped, and increase the "as received" percent passing of the other sizes in the same proportion.

   Example: Assume an aggregate which has a grading with 90 % passing the 19 mm sieve and the sample has to be scalped on the 19 mm sieve. The "as used" grading is calculated as follows:

Sieve	As Received Percent Passing	Calculations	As Used Percent Passing
37.5 mm	100		
25.0 mm	95		
19.0 mm	90		100
9.5 mm	80	(100/90) x 80	89
4.75 mm	70	(100/90) x 70	78

   The percentages of material passing the sieve sizes smaller than the 4.75 mm sieve are computed in the same manner.

2. Single sample with a portion of the passing 4.75 mm material to be wasted.

   It is frequently necessary to waste a portion of the passing 4.75 mm material in order to bring the grading into specifications. The procedure can best be explained by an example.

   Example: Given an aggregate with the following grading:

Sieve Size	Percent Passing
19.0 mm	100
9.5 mm	90
4.75 mm	70
2.36 mm	55

It is necessary to reduce the percent passing the 4.75 mm sieve from 70 % to 60 % in order to conform to specifications.

The new grading will be:

Sieve Size	Percent Passing
19.0 mm	100
9.5 mm	60 + (90 - 70) [(100 - 60) / (100-70)] = 87
4.75 mm	60
2.36 mm	(60 / 70) x 55 = 47

Sizes smaller than the 2.36 mm sieve are computed in the same manner as for the 2.36 mm sieve.

It is generally desirable to know what percentage of the total sample is to be wasted. The following method may be used:

Consider a unit amount of material:

Let W = Percent of the total sample to be wasted

P_1 = Original percent passing 4.75 mm sieve

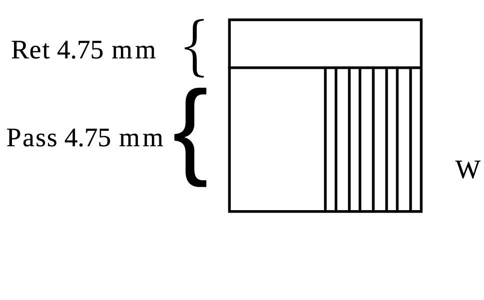
P_2 = Final percent passing 4.75 mm sieve

Then:

$$W = [(P_1 - P_2) / (100 - P_2)] \times 100$$

$$= [(70 - 60) / (100 - 60)] \times 100$$

= 25 % of total sample wasted



3. Single sample with a portion of the retained 4.75 mm material to be wasted.

The following example illustrates a method of adjusting grading by wasting a portion of the retained 4.75 mm material.

Given an aggregate with the following grading:

Sieve Size	Percent Passing
19.0 mm	100
9.5 mm	90
4.75 mm	70
2.36 mm	40

It is necessary to waste enough of the retained 4.75 mm sieve size fraction to increase the percent passing the 4.75 mm sieve from 70 % to 80 %.

The new grading will be:

Sieve Size	Percent Passing
19.0 mm	100
9.5 mm	80 + (90 - 70) [(100 - 80) / (100-70)] = 93
4.75 mm	80
2.36 mm	(80 / 70) x 40 = 46

Sizes smaller than the 2.36 mm sieve are computed in the same manner as for the 2.36 mm sieve.

It is generally desirable to know what percentage of the total sample is to be wasted. The following method may be used.

Consider a unit amount of material:

Let W = Percent of the total sample to be wasted

R_1 = Percent retained 4.75 mm originally

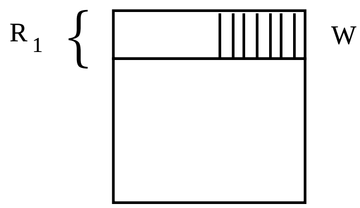
R_2 = Percent retained 4.75 mm finally

Then:

$$W = [(R_1 - R_2)/(100 - R_2)] \times 100$$

$$= [(30 - 20)/(100 - 20)] \times 100$$

$$= 12.5\ \%\ \text{of total sample wasted}$$



4. Single sample with all of the material passing the 4.75 mm sieve to be wasted. Subtract the percent passing the 4.75 mm sieve from each sieve size retained, then readjust to equal 100 %.

Sieve Size	Original Grading	Subtraction	Corrected to 100 %*
19.0 mm	100	100 — 53 = 47	100
12.5 mm	82	82 — 53 = 29	62
9.5 mm	73	73 — 53 = 20	43
4.75 mm	53	53 — 53 = 0	0
2.36 mm	37		
1.18 mm	24		
600 µm	15		

* 47:100::29:X X = 62
47:100::20:X X = 43, etc.

5. Single sample with a portion of the passing 75 µm sieve size material to be wasted. The percent of material wasted is subtracted from the percent passing each sieve size. This gives a grading less than 100 %, which is corrected proportionately to equal 100 %.

   Example: From a sample it is desired to remove material passing the 75 µm sieve in order to meet specific grading.

Sieve Size	Original Percent Passing	Waste 3 Percent Passing No. 200	Proportion to 100 % ‡	Specified Limits Percent Passing
19.0 mm	—	—	—	100
12.5 mm	100	97	100	95-100
9.5 mm	83	80	82	75-90
4.75 mm	55	52	54	50-67
2.36 mm	43	40	41	35-50
1.18 mm	35	32	33	—
600 µm	28	25	26	15-30
300 µm	22	19	20	—
150 µm	16	13	13	—
75 µm	10	7	7	4-7

‡97:100::80::X X = 82
Also
97:100::52:X X = 54, etc.

To waste the passing 75 µm for laboratory testing the waste will be made from the material passing the 4.75 mm sieve previously separated when processed and graded. For example:

10 000 g of material, graded from coarse to fine, will be required for the tests and passing 75 µm material equivalent to 3 % of the sample must be wasted from the total sample.

Therefore:

10 000 / (100 – 3) = 10 309 g total amount of material before wasting.

10 309 – 10 000 = 309 g of the material passing 75 µm sieve be screened out of the total sample.

Since 55 % of the 10 000 g needed for testing is passing the 4.75 mm sieve, it follows that 0.55 x 10 000 = 5500 g of passing 4.75 mm material will be needed after wasting, and 5500 + 309 = 5809 g of the passing 4.75 mm material will be the amount necessary to use before screening out the passing 75 µm material.

NOTE: In most instances it should be possible to remove the passing 75 µm material by dry sieving; however, when large quantities are to be removed, it will probably be necessary to employ washing.

The percentage of material passing the 4.75 mm sieve is held constant and the percentage passing the 25.0 mm sieve is equated to 100 %. The intermediate sizes, between the 25.0 mm and 4.75 mm, are proportioned in the same ratio as the original grading.

The following example shows a grading before and after the retained 25.0 mm material has been replaced by that passing 25.0 mm and retained on the 4.75 mm sieve.

Sieve Size	As Received Grading Percent Passing		Adjusted Grading Percent Passing
37.5 mm	100		
25.0 mm	90		100
19.0 mm	80	60 + [(20 x 40) / 30)] =	87
9.5 mm	70	60 + [(10 x 40) / 30)] =	73
4.75 mm	60		60

C. GRADING ADJUSTMENTS ON MULTIPLE SAMPLES

1. Combining two or more samples. The first step is to decide what proportion of each sample to use. This generally depends upon the specification requirements. It is usually quicker to use the trial method for arriving at the proportions. An experienced operator can usually determine the proportions in the first or second trial.

   Example: Assume combination consisting of 80 % of sample No. 1, and 20 % of sample No. 2.

Sieve Size	As Received Percent Passing Sample No. 1	As Received Percent Passing Sample No. 2	Proportioned Grading 80 % No. 1	Proportioned Grading 20 % No. 2	Combined Percent Passing	As Used (Scalp 19.0 mm) Percent Passing
25.0 mm	100	100	80	20	100	
19.0 mm	90	100	72	20	92	100
9.5 mm	80	95	64	19	83	90
4.75 mm	70	90	56	18	74	80

2. Crushing oversize from sample and recombining with uncrushed material. The gradings are considered individually; i.e., crushed and uncrushed. Each grading is then proportioned as to its relative percentage of the original sample and recombined.

   Example: A sample was separated on the 19.0 mm sieve. The oversize, 46 %, was crushed to pass the 19.0 mm sieve, then recombined with the original portion.

Sieve Size	Original sample Percent passing	Oversize crushed Percent passing	Proportioning		Combined sample original & crushed
19.0 mm	54	100	100 x .46 = 46	54 + 46	100
9.5 mm	45	56	56 x .46 = 26	45 + 26	71
4.75 mm	39	35	35 x .46 = 16	39 + 16	55
2.36 mm	37	20	20 x .46 = 9	37 + 9	46
1.18 mm	34	15	15 x .46 = 7	34 + 7	41
600 µm	20	11	11 x .46 = 5	20 + 5	25
300 µm	16	9	9 x .46 = 4	16 + 4	20
150 µm	10	8	8 x .46 = 4	10 + 4	14
75 µm	4	4	4 x .46 = 2	4 + 2	6

3. Wasting material from the uncrushed portion of sample in which the oversize is crushed. When an adjustment is necessary to produce a specified grading from a sample that has had the oversize crushed, the wasted material shall be taken from the uncrushed portion of the aggregate. This will change the proportions of crushed and uncrushed, and an adjustment is necessary.

Example: From a sample having originally 50 % uncrushed and 50 % crushed, it was necessary to waste a portion of the total sample equivalent to 25 % in order to conform to the grading requirement. This 25 % is to be removed from the uncrushed portion and it is desired to obtain the proportions of crushed and uncrushed after this material has been wasted.

Let W = Percent of total to be wasted

X = Original percent uncrushed

X_1 = Final percent uncrushed

Y = Original percent crushed

Y_1 = Final percent crushed

$X + Y = 100$, also $X_1 + Y_1 = 100$

$$(100 - W)/100 = (X - W)/X_1$$

Then:

$$X_1 = [(X - W)/(100 - W)] \text{ x } 100$$

Also, $(100 - W)/100 = Y/Y_1$

$$Y_1 = [Y/(100 - W)] \text{ x } 100$$

Substituting into the above equation,

$X_1 = [(50 - 25)/(100 - 25)] \text{ x } 100 = [25/75] \text{ x } 100 = 33$ %

Also, $Y_1 = [50/(100 - 25)] \text{ x } 100 = [50/75] \text{ x } 100 = 67$ %

The final grading will contain 33 % uncrushed and 67 % crushed material.

4. Wasting a portion of the passing 75 µm sieve material from a combined sample of natural and crushed material. Blend sample as directed by paragraph B, then subtract the percent of passing 75 µm material to be wasted from each sieve size, and proportionately adjust sample to equal 100 %.

Example:

Sieve Size	% pass. of nat. mat'l.	% pass. of crushed mat'l.	Com-bined % passing	Waste 3% of pass. 75 µm	Propor-tion to 100%	Final % of nat. mat'l.	Final % of crushed mat'l.	Final grading
25.0 mm	—	—	—	—	—	—	—	—
19.0 mm	—	—	—	—	—	—	—	—
12.5 mm	79	21	100	97	100	78	22	100
9.5 mm	69	14	83	80	82	68	14	82
4.75 mm	48	7	55	52	54	46	7	53
2.36 mm	39	4	43	40	41	37	4	41
1.18 mm	32	3	35	32	33	30	3	33
600 µm	25	3	28	25	26	23	3	26
300µm	19	3	22	19	20	16	3	19
150 µm	14	2	16	13	13	11	2	13
75 µm	8	2	10	7	7	5	2	7

To screen out and waste the passing 75 µm for testing, the waste shall be made from the uncrushed material passing the 4.75 mm sieve size whenever possible.

Example: Material needed for testing:

3	Stabilometer specimens	3600 g
2	Moisture vapor susceptible specimens	2400 g
2	Swell specimens	2000 g
	Additional material for CKE, SE, etc.	1000 g
	Total material needed	9000 g

9000 / (100 – 3) = 9278 g combined natural and crushed materials needed before wasting.

9278 – 9000 = 278 g of passing 75 µm to be screened out and wasted from the natural material.

Since the natural material minus 4.75 mm sieve size material is 48 % of the total sample, then:

0.48 x 9000 = 4320 g of passing 4.75 mm natural material needed.

4320 + 278 = 4598 g of passing 4.75 mm natural material to weigh out before screening out and wasting 278 g passing 75 µm sieve size material.

D. CORRECTION FOR VARIATION IN SPECIFIC GRAVITY OF MINERAL AGGREGATE

1. Grading analyses and grading limits of mineral aggregates are generally expressed as a percentage by mass of the total passing each sieve size. However, this method of expression is correct only when the aggregates are of uniform specific gravity. To correctly show particle size distribution, it is necessary to consider the grading analysis from a "by volume" basis; consequently when variation in specific gravity between the fine and coarse material exceeds 0.20, it will be necessary to compensate for this variation in order to obtain and batching mass that will produce the proper volumetric proportions. This is accomplished by use of the average specific gravity of the aggregate.

2. Let us assume that we have two stockpiles of aggregates that we are going to use for producing a bituminous paving mixture. One stockpile contains the passing 4.75 mm aggregates having a specific gravity of 2.73 and the other containing the retained 4.75 mm aggregates having a specific gravity of 2.32, a difference of 0.41. These stockpiles are to be blended in the proper proportions to conform to specified grading limits. To demonstrate the effect this 0.41 variation in specific gravity has upon the volumetric proportions of the mixture, the following example is given. All calculations used in the various stages of the example will be described in order of their use at the conclusion of the text.

3. The first step is to combine the retained 4.75 mm and the passing 4.75 mm materials in "by mass" proportions that will produce a grading conforming to the specified limits irrespective of the specific gravity. The grading, as shown under (1) represents proportions "by mass" of 49 % and 51 %, respectively, of the retained 4.75 mm and passing 4.75 mm stockpiled materials. With the difference of 0.41 in specific gravity, the next step is to determine whether or not a "by volume" grading produced from material batched "by mass" from the grading shown under (1) would conform to the grading limits. When the grading was corrected to "by volume" (as in 2) by means of the average specific gravity of the aggregate, it was found to be out of grading limits on the 4.75 mm and 2.36 mm sieves. The correction to "by volume" had changed the percentage passing the 4.75 mm sieve from 51 % to 47 % with other amounts passing the various sieves changing proportionately. To produce a grading conforming to specification limits from these materials, it was necessary to arbitrarily adjust the "by mass" proportioning of the stockpiles (as shown in 3). For this adjustment, the percentage "by mass" was changed from 51 % to 54 % with other amounts passing the various sieves changed proportionately. Step (4) simply involves changing the "by mass" grading in (3) to "by volume." With this correction, the 54 % "by mass" amounts to 50 % "by volume," with other amounts passing the various sieve sizes changed proportionately.

		(1)	(2)	(3)	(4)
Sieve size	Grading limits	"By mass" blend of stockpiles conforming to spec, grading limits percent passing	Corrected to "by volume" percent passing	"By mass" grading adjusted to produce "by volume" grading conforming to specs percent passing	Final "by volume" grading percent passing
19.0 mm	100	100	100	100	100
9.5 mm	60-75	65	62	67	64
4.75 mm	50-65	51	47	54	50
2.36 mm	37-50	38	35	40	37
1.18 mm	—	29	27	31	29
600 µm	18-28	19	18	21	19
300 µm	—	14	13	15	14
150 µm	—	9	8	9	8
75 µm	3-8	4	4	5	5

Specific gravity, coarse = 2.32
Specific gravity, fine = 2.73

Formulae and calculations for the example are:

Ga = $100/[(Pm_1/G_1) + (Pm_2/G_2)]$

Pv = $(PmGa)/G$

Ga = Average specific gravity of aggregate

Pm = Percent of sample by mass

G = Specific gravity of aggregate

Pv = Percent of sample by volume

(1) Grading produced by combining retained 4.75 mm and passing 4.75 mm stockpiles in proportions of 49 % and 51 % by mass, respectively, without considering specific gravity.

(2) Grading corrected to "by volume."

Average specific gravity =
$100/[Pm_1/G_1) + (Pm_2/G_2)] =$
$100/[(49/2.32) + (51/2.73)] = 2.51$

Percent retained 4.75 mm =
$(PmGa)/G = (49 \text{ x } 2.51)/2.32 = 53\ \%$

Percent pass 4.75 mm =
$(PmGa)/G = (51 \text{ x } 2.51)/2.73 = 47\ \%$

Change remainder of grading in proportion to the change from 51 % to 47 % on the passing 4.75 mm, for example:

Passing 9.5 mm =
$47 + (65 - 51)\ [(100 - 47)/(100 - 51)] = 62$

Passing 2.36 mm = $(47/51) \text{ x } 38 = 35$

(3) "By mass" grading determined by trial adjustment that will, after correcting to absolute volume, conform to the specified grading limits.

(4) Adjusted "by mass" grading corrected to absolute volume.

Average specific gravity =
$100/\ [(Pm_1/G_1) + (Pm/G_2)] =$
$100/[(46/\ 2.32) + (54/2.73)] = 2.52$

Percent retained 4.75 mm =
$(PmGa)/G = (46 \text{ x } 2.52)/2.32 = 50\ \%$

Percent pass 4.75 mm =
$(PmGa)/G = (54 \text{ x } 2.52)/2.73 = 50\ \%$

Change remainder of grading in proportion to the change from 54 % to 50 % as in (2).

E. PRECAUTIONS

No adjustment to gradings should be made in the laboratory that cannot be economically duplicated in the field. The limitations of the screening plants, crushers, hot plants, and mixers should be recognized.

F. SAFETY AND HEALTH

Prior to handling, testing or disposing of any materials, testers are required to read Caltrans Laboratory Safety Manual: Part A, Section 5.0, Hazards and Employee Exposure; Part B, Sections: 5.0, Safe Laboratory Practices; 6.0, Chemical Procurement Distribution and Storage; and 10.0, Personal Protective Apparel and Equipment; and Part C, Section 1.0; Safe Laboratory Practices. Users of this method do so at their own risk.

End of Text (California Test 105 contains 7 pages)